

APPLICATION
FOR
UNITED STATES LETTERS PATENT

TITLE: REAL-TIME MONITORING OF PARTICLES IN
SEMICONDUCTOR VACUUM ENVIRONMENT

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Real-Time Monitoring of Particles in Semiconductor Vacuum
Environment

TECHNICAL FIELD

This invention relates to real-time monitoring of
5 particles in a semiconductor vacuum environment.

BACKGROUND

A microprocessor is an integrated circuit (IC) built
on a tiny piece of silicon. A microprocessor contains
10 millions of transistors interconnected through fine wires
made of aluminum or copper.

Microprocessor fabrication is a complex process
involving many steps. Microprocessors are typically built
by layering materials on top of thin rounds of silicon,
15 called wafers, through various processes using chemicals,
gases and light. In chip making, very thin layers of
material, in carefully designed patterns, are put on the
blank silicon wafers. The patterns are computerized designs
that are miniaturized so that up to several hundred
20 microprocessors can be put on a single wafer.

Because the patterns are so small, it is nearly
impossible to deposit material exactly where it needs to be
on the wafer. Instead, a layer of material is deposited or
grown across an entire wafer surface. Then, the material
25 that is not needed is removed and only the desired pattern
remains.

The microprocessor fabrication process begins with
"growing" an insulting layer of silicon dioxide on top of a
polished wafer in a high temperature furnace.
30 Photolithography, a process in which circuit patterns are

printed on the wafer surface, is next. A temporary layer of a light sensitive material called a "photoresist" is applied to the wafer. Ultraviolet light shines through clear spaces of a stencil called a "photomask" or "mask" to
5 expose selected areas of the photoresist. Masks are generated during a design phase and are used to define a circuit pattern on each layer of a chip. Exposure to light chemically changes the uncovered portions of the photoresist. The machine used to do this is typically
10 called a "scanner" because it scans one die or a few die at a time, then steps to the next die or set of die until it has exposed the entire wafer.

An active area of the mask is exposed to a vacuum environment of a scanner and is at high risk of
15 accumulating particles. If a particle lands in a critical part of the active area then it will lead to a printed defect on the wafer. This defect causes decreased yields, or increased wafer cost in rework if the defect is fortuitously caught prior to further wafer processing by
20 wafer defect metrology.

DESCRIPTION OF DRAWINGS

FIG. 1 is a block diagram of an exemplary optical projection lithography system.

FIG. 2 is a block diagram of a stage.

25 FIG. 3 is a block diagram of an exposed semiconductor component.

FIG. 4 is a flow diagram of a real-time particle monitoring process.

Like reference symbols in the various drawings
30 indicate like elements.

DETAILED DESCRIPTION

The systems and techniques described here relate to real-time monitoring of particles in vacuum environments of semiconductor processing equipment. For ease of

5 discussion, a photolithography process of a semiconductor fabrication is used as an example for describing the real-time monitoring of particles in vacuum chambers of semiconductor processing equipment. However, the systems and techniques described herein are not limited to
10 photolithography; rather, they can be used in any semiconductor vacuum process environment in which a real-time monitoring of particles is needed, such as while depositing a film on a semiconductor wafer or implanting a dopant on a semiconductor wafer.

15 A semiconductor manufacturing process hinges on a use of a photographic process to generate fine featured patterns of an integrated circuit (IC). Each layer of a chip is defined by a specific mask. A mask is somewhat like a photographic negative, which is made by patterning a
20 film of chromium on a pure quartz glass plate. The finished plates are referred to as reticles. Reticles are manufactured by sophisticated and expensive pattern generation equipment, which is driven from a chip design database. The patterns are formed on the chromium plated
25 quartz by removing the chromium with either laser or electron-beam driven tools.

Referring to FIG. 1, an exemplary optical projection lithography system 10, such as an extreme-ultraviolet (EUV) lithography system, is shown. Optical projection
30 lithography is the technology used to print the intricate patterns that define integrated circuits onto a

semiconductor wafer 12. The system 10 includes an illuminator enclosure 14, a mask-stage chamber 16, a camera chamber 18 and a wafer-stage chamber 20.

5 The illuminator enclosure 14 includes laser optics that, for example, generate EUV light from a plasma generated when a laser illuminates a jet of xenon gas. The light is collected and focused on a mask 22 residing on a mask stage 24 in the mask-stage chamber 16 by a series of condenser mirrors 26a, 26b, 26c, 26d. A mask image is
10 projected onto the wafer 12 by a reduction camera 28a, 28b, 28c, 28d, while the mask 22 and wafer 12 are simultaneously scanned. The entire operation takes place in high-vacuum environmental chambers and is controlled by a computer system 29.

15 Impurities 32, such as metallic and/or non-metallic particles, can be present in the mask-stage chamber 16. If one of the particles 32 lands on a critical part of an active area of the mask 22 it will lead to a printed defect on the wafer 12. This defect causes decreased yields, or
20 increased wafer cost in rework if the defect is detected at an early stage. The present invention provides a real-time detection of the presence of particles in the vicinity of the mask 22 that would warrant stoppage of the lithography system 10. In an extreme-ultraviolet (EUV) lithography
25 environment, particle sizes that are estimated to be of concern are on the order of 50 nanometers (nm).

As shown in FIG. 2, the mask stage 24 includes a placement of one or more active semiconductor components 30 near the mask 22 and embedded within the mask stage 24.
30 The active semiconductor components 30 can include any

number of different devices that function to detect particles that land on them.

As shown in FIG. 3, each active semiconductor component 30 includes one or more devices 31. Each device 5 31 includes a pair of conductive lines 34, 36 exposed to a local vacuum environment within the mask-stage chamber 16. The conductive lines 34, 36 of the device 31 are spaced at a critical pitch corresponding to the smallest particle diameter of interest. A voltage is applied to the 10 conductive lines 34, 36 of the device 31. A metallic particle having a diameter the size of the pitch between the conductive lines 34, 36, or larger, generates a short in a current flow between the conductive lines 34, 36. A non-metallic particle having a diameter the size of the 15 pitch between the conductive lines 34, 36, or larger, generates a change in capacitance between the conductive lines 34, 36. The short and/or change in capacitance is detected by the computer system 29. Detection of such particle(s) provides a warning that particles are in the 20 vicinity of a critical part of the tool, such as near the mask 22 in this lithography example. When detected, corrective action can be taken, such as terminating the lithography process before the particles cause imperfections in the wafer 12. In one particular 25 embodiment, the short and/or change in capacitance is detected by off-chip circuitry (not shown).

A number of these devices 31 can be located in the semiconductor device 30 providing determination of particle density counts. Devices 31 sensitive to various particle 30 sizes, e.g., by varying the pitch of the pairs of lines, can also be incorporated into the active semiconductor

component 30 to monitor a range of particle sizes through a region or regions of interest.

In a particular embodiment, each active semiconductor component 30 is protected by a remote-controlled removable
5 cover (not shown) until the component 30 is ready to be exposed to a vacuum environment. The cover is remotely triggered by the computer system 29 or other triggering mechanism (not shown) to open when desired, exposing the device 31 to the vacuum environment.

10 As shown in FIG. 4, a real-time monitoring process 100 for detecting particles in a semiconductor vacuum environment includes exposing (102) a particle detecting integrated circuit embedded in a stage to residual gases and particles within a vacuum environment. The particle
15 detecting integrated circuit includes a device having a pair of conductive lines spaced at a critical pitch corresponding to diameters of particles of interest.

Process 100 applies (104) a voltage to the pair of conductive lines and detects (106) a change in an
20 electrical property of the conductive lines resulting from a particle landing on or between the pair of conductive lines. A metallic particle having a diameter the size of the pitch between the lines, or larger, generates a short in a current flow between the lines. A non-metallic
25 particle having a diameter the size of the pitch between the lines, or larger, generates a change in capacitance between the lines. The short and/or change in capacitance is detected by the computer system. Once detected, corrective action can be initiated.

30 Other embodiments are within the scope of the following claims.